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Specification and Drawings, as originally filed, with Application for Patent Serial No:
2,424,630, on April 7, 2003, by **MARKO I.R.D.C. INC.**, assignee of Julien Lefebvre,
Michel Legaré, Mark Frohlich, Ludovic Leplatois and Roger Tambay, for "Reflective Film".

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REFLECTIVE FILM

ABSTRACT

The present invention provides a reflective film that can be adhered to a surface of a construction material to form a composite material that is useful as radiant heat insulation in industrial, commercial and residential buildings. The reflective film comprises a layer of aluminum foil adhered to a surface of a polyethylene film. Also provided is an alternative in which the reflective film comprises a layer of aluminum foil adhered to polyethylene-coated kraft paper. The polyethylene film or polyethylene-coated kraft paper composite is formulated such that reflective film may be laminated to the surface of the construction material without the use of an adhesive.

FIELD OF THE INVENTION

The present invention pertains to the field of reflective films. In particular, the present application pertains to reflective films comprising a layer of aluminum foil.

BACKGROUND

5 Roof decking is typically made from sheets of plywood, oriented strand board (OSB) or the like, which are nailed or otherwise fastened to structural members, such as rafters, defining the roof of a building. This structure provides little insulation, the insulative properties of the roof structure being limited to that of the materials themselves. Typically, efforts to improve the insulative or heat emitting properties of the roof have been limited to application of insulative
10 materials to the exterior of the roof decking under the water-shedding materials, or of insulative or reflective materials below the roof decking.

 Improvements to the typical methods for increasing the insulative or heat emitting properties of roof structures have resulted in the production of radiant sheathing materials. For example, U.S. Patent No. 5,231,814 provides a decking or sheathing material for roofing that
15 includes a sheet of plywood or OSB with a reflective layer of foil material attached thereto. The foil material may include a layer of kraft paper backing in addition to a layer of metallic foil, such as aluminum. The foil layer may be perforated to eliminate problems associated with trapped moisture in the structural materials made of wood. The perforations permit the materials to "breathe".

20 Despite the improved insulative and reflective properties provided by such material, there are numerous drawbacks associated with the construction of sheathing materials similar to those disclosed in U.S. Patent No. 5,231,814. The construction of such materials requires that an adhesive be used to attach the foil material to the structural material. This requires a reliable method for producing uniform adhesion of the foil material to the structural material, which is
25 not often possible. Products of this type are often characterised by defects as a result of non-uniform adhesion of the foil material. Furthermore, the process for adhering the foil material to the structural material, such as OSB, which is heated during its production, requires that the

structural material be cooled prior to adhesion. This can add a significant amount of time to the manufacturing process.

A common problem of the kraft paper, which is a material disclosed in US Patent No. 5231814 is that it deteriorates when the board is left outside, unprotected from rain and humidity while on the construction site or on when applied as a roofing structure but before shingles are installed.

It is also known, in building constructions such as residential stud wall framing, to provide an air barrier in order to substantially reduce or prevent air infiltration into or out of the building envelope. As well, use of a vapour barrier is known to prevent moisture present in the building interior from passing into insulation which has been applied to the structure. In cold climates, the vapour barrier prevents ingress and subsequent freezing of any moisture in the insulation installed in the stud wall cavities. The use of air barriers and vapour barriers is mandated by many building codes. In warm climates, the radiant sheathing prevents heat radiant or IR heat from penetrating the attic. This is known to reduce attic temperatures by as much as 30 deg. F and which in turn reduces heat load of the house interior and therefore reduce electricity consumption by air-conditioning units.

It is known that the air barrier may be comprised of sheathing on the exterior of a stud wall structure, or may be combined with the vapour barrier on the interior of the stud wall structure. Typically, a combined air and vapour barrier has been formed from polyethylene or polypropylene film of varying thicknesses, typically 6 to 8 mils.

In a conventional stud wall structure, therefore, typically there will be positioned an exterior sheathing material. The sheathing is attached to a stud wall structure comprising top and bottom plates and intermediate vertical studs, typically of 4-6 inch thickness. Countries having seasonally cold climates normally utilize insulation in the walls to prevent loss of heat during the cold seasons. Accordingly insulation such as glass fiber or rock wool material is inserted between the studs. A vapour barrier of polyethylene film is glued or stapled to the interior of the stud wall face, and an interior finishing material such as gypsum board, plaster board or other panelling material is applied directly over the vapour barrier. In the type of construction described above, the mechanical structure as well as vapour and air barriers required by typical

building codes is provided. However, this minimal structure is subject to degradation over time, and does not provide other attributes which may be desirable in residential construction.

A need remains for a reflective film that is capable of being laminated to construction materials without the use of adhesive.

5 This background information is provided for the purpose of making known information believed by the applicant to be of possible relevance to the present invention. No admission is necessarily intended, nor should be construed, that any of the preceding information constitutes prior art against the present invention.

SUMMARY OF THE INVENTION

10 An object of the present invention is to provide a reflective film. In accordance with an aspect of the present invention, there is provided a reflective film comprising a polyethylene film, or film composite, with a layer of aluminum foil laminated to a surface thereof, wherein said reflective film can be laminated to a construction material without the use of an adhesive. In accordance with a related aspect of the present invention there is provided a reflective film for
15 adhesion to a construction material, which reflective film comprises a layer of converter grade aluminum foil, preferably soft and oil-free, having a thickness of between about 0.00025 mil and about 2 mil adhered to one surface of a polyethylene film or film composite, said polyethylene film or film composite having a surface energy of at least 35 dynes and consisting of:

- 20 ■ a first outer portion suitable for adhesion to the construction material consisting of one or more layers of: (i) a 6 – 28% EVA with melt index of 0.5 – 30; (ii) a metallocene catalyzed polyethylene with density below 0.905 g/mL and melt index between 0.5 – 30; (iii) an acid modified copolymer of polyethylene with a melt index of 0.5 to 30; (iv) an ionomer (example: Surlyn by DuPont) with a melt index of 0.5 to 30; (v) an ethyl methyl acrylate polyethylene copolymer with a melt index of 0.5 to 30; (vi) an ethyl butyl acrylate
25 polyethylene copolymer with a melt index of 0.5 to 30; (vii) an ethyl ethylene acrylate polyethylene copolymer with a melt index of 0.5 to 30; or (viii) a combination of one or more of (i), (ii), (iii), (iv), (v), (vi), or (vii) alone or blended with between 0 and 80 % of a low density polyethylene having a melt index of 0.3 – 30; and

- a second outer portion adhered to the layer of aluminum foil and consisting of one or more layers of: (i) an ethylene acrylic acid modified polyethylene; (ii) an ionomer, (iii) a low density polyethylene with a melt index between 0.5 – 30; or (iv) a combination thereof.

The reflective film optionally includes a middle portion consisting of one or more layers of: (i) a low density polyethylene with a melt index of 0.3 – 30; (ii) a linear low density polyethylene with a density below 0.930 g/mL and melt index between 0.5-30; (iii) a polyethylene with a density of above 0.930 g/mL and melt index between 0.5 – 30; (iv) a 6 – 24 % EVA with a melt index of 0.5 – 30; (v) a polypropylene; (vi) any combination of two or more of (i), (ii), (iii), (iv) or (v); or (vi) kraft paper.

In accordance with another aspect of the present invention there is provided a composite comprising a reflective film laminated to one side of a construction material, wherein the reflective film comprises a layer of a converter grade aluminum foil, preferably soft and oil-free having a thickness of between about 0.00025 mil and about 2 mil adhered to one surface of a polyethylene film or film composite, said polyethylene film or film composite having a surface energy of at least 35 dynes and consisting of:

- a first outer portion suitable for adhesion to the construction material consisting of one or more layers of : (i) a 6 – 28% EVA with melt index of 0.5 – 30; (ii) a metallocene catalyzed polyethylene with density below 0.905 g/mL and melt index between 0.5 – 30; (iii) an acid modified copolymer of polyethylene with a melt index of 0.5 to 30; (iv) an ionomer (example: Surlyn by DuPont) with a melt index of 0.5 to 30; (v) an ethyl methyl acrylate polyethylene copolymer with a melt index of 0.5 to 30; (vi) an ethyl butyl acrylate polyethylene copolymer with a melt index of 0.5 to 30; (vii) an ethyl ethylene acrylate polyethylene copolymer with a melt index of 0.5 to 30; or (viii) a combination of one or more of (i), (ii), (iii), (iv), (v), (vi), or (vii) alone or blended with between 0 and 80 % of a low density polyethylene having a melt index of 0.3 – 30; and
- a second outer portion adhered to the layer of aluminum foil and consisting of one or more layers of: (i) an ethylene acrylic acid modified polyethylene; (ii) an ionomer, (iii) a low density polyethylene with a melt index between 0.5 – 30; or (iv) a combination thereof; and, optionally,

- middle portion consisting of one or more layers of: (i) a low density polyethylene with a melt index of 0.3 – 30; (ii) a linear low density polyethylene with a density below 0.930 g/mL and melt index between 0.5-30; (iii) a polyethylene with a density of above 0.930 g/mL and melt index between 0.5 – 30; (iv) a 6 – 24 % EVA with a melt index of 0.5 – 30; (v) a polypropylene; (vi) any combination of two or more of (i), (ii), (iii), (iv) or (v); or (vi) kraft paper,

and wherein the reflective film is directly adhered to the construction material such that the layer of aluminum foil forms a surface of the composite.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 provides an exploded view of the composite according to one embodiment of the present invention.

Figure 2 is a graphical depiction of a simulation of wood panel cooling (—◆— wood panel temperature profile; —■— oven temperature profile).

Figure 3 is a graphical representation of the influence of the inter-grip distance on peel strength.

Figure 4 is a graphical representation of the influence of the peeling velocity on peel strength.

Figure 5 is a graphical representation of the influence of formulation and processing temperature and pressure on adhesion strength of a reflective film according to one embodiment of the present invention (—◆— formulation 1, 40 psi; —■— formulation 1, 110 psi; -◆- formulation 2, 40 psi; —■— formulation 2, 110 psi; ·◆· formulation 3, 40 psi; ·■· formulation 3, 110 psi).

Figure 6 is a graphical representation of the influence of formulation and processing temperature on adhesion strength of a perforated reflective film according to one embodiment of the present invention (—■— formulation 1, 110 psi; —■— formulation 2, 110 psi; ---■--- formulation 3, 110 psi).

Figure 7 is a graphical representation of the effect of ageing a composite according to one embodiment of the present invention under wet conditions (■ formulation 1, 110 psi, 75 °C; ■ formulation 2, 110 psi, 120 °C; ■ formulation 3, 75 psi, 120 °C; ■ paper (bottom symbol at each time)).

5

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a reflective film useful for lamination to the surface of a construction material without the use of an adhesive. The present invention further provides a composite comprising the reflective film, which is laminated to a surface of a construction material.

10 Reflective Film Components

The reflective film of the present invention comprises a polyethylene film formulated to allow the reflective film to be laminated to a surface of a construction material without the use of an adhesive. One surface of the polyethylene film has a surface energy of at least 35 dynes and is uniformly adhered to a layer of converter grade aluminum foil having a thickness of between
15 about 0.00025 mil and about 2 mil.

In describing the components of the reflective film or film composite of the present invention, it is understood that all percentages listed are referring to weight percentages.

Polyethylene film

The reflective film of the present invention comprises a polyethylene film having a
20 thickness of between 1 and 10 mil, or optionally 2 to 4 mil, wherein at least one surface of the film has a surface energy of at least 35 dynes. The polyethylene film comprises one or more layers of polyethylene, low density polyethylene, a polyethylene copolymer or a combination thereof.

In one embodiment of the present invention the reflective film comprises a polyethylene
25 film or film composite that consists of three portions. One outer portion of the polyethylene film

or film composite is formulated for adhesion to a construction material and the other outer portion is formulated for adhesion to the layer of aluminum foil.

The first outer portion, referred to herein as Portion A, is for adhesion to the construction material and can comprise one or more layers of:

- 5 (i) a 6 – 28 % ethylene vinyl acetate (EVA) with melt index of 0.5 – 30, such as AT Plastics' ATEVA® 1018 (which has a melt index of 16, with a likely range between 14 and 18);
- (ii) a metallocene catalyzed polyethylene with density below 0.905 g/mL and melt
10 index between 0.5 – 30, such as Dow Chemical Company's AFFINITY™ PF 1140 (which has a melt index of 1.2, with a likely range between 1.0 and 1.4) or PL 1880 (which also has a melt index of 1.2, with a likely range between 1.0 and 1.4);
- (iii) an acid modified copolymer of polyethylene with a melt index of 0.5 to 10, such
15 as Dupont Nucrel® 3100 (which has a melt index of 2, with a likely range of 1 to 3) or Dupont Bynel™ 5100 or Dupont Nucrel® AE (which has a melt index of 11, with a likely range of 6 to 15);
- (iv) an ionomer, such as Dupont Surlyn® EC1605, Dupont Surlyn® BF1660;
- (v) an ethyl methyl acrylate polyethylene copolymer with a melt index of 0.5 to 30,
20 such as Eastman EMAC 2207 (which has a melt index of 2, with a likely range of 1 to 3) or Dupont Elvaloy® 1609 (which has a melt index of 6, with a likely range of 4 to 8);
- (vi) an ethyl butyl acrylate polyethylene copolymer with a melt index of 0.5 to 30,
such as Dupont Elvaloy® 3427 AC (which has a melt index of 4, with a likely range of 2 to 6);
- 25 (vii) an ethyl ethylene acrylate polyethylene copolymer with a melt index of 0.5 to 30, such as Dupont Elvaloy® 2112 (which has a melt index of 6, with a likely range of 4 to 8); or

- (viii) a combination of one or more of (i), (ii), (iii), (iv), (v), (vi) or (vii) alone or in combination with 0 and 80 % of a low density polyethylene with a melt index of 0.3 – 30, such as Eastman Tenite™ E6838-969F (which has a melt index of 0.7, with a likely range of 0.5 to 0.9).

5 The other outside portion, referred to herein as Portion C, is for adhesion to the layer of aluminum foil and can comprise one or more layers of:

- (i) an ethylene acrylic acid modified copolymer of polyethylene with a melt index of 0.5 to 15, such as Dupont Nucrel® 3100 or Dupont Bynel™ 5100;
- (ii) an ionomer;
- 10 (iii) a low density polyethylene with a melt index of 0.5 – 30, such as Eastman Tenite™ E6838-969F; or
- (iv) any combination thereof.

In a related embodiment of the present invention the reflective film comprises a polyethylene film that consists of three portions. The outer portions are as described above and
15 are formulated for adhesion to a construction material and for adhesion to the layer of aluminum foil, respectively. The reflective film that consists of three portions additionally includes a middle portion, referred to as Portion B, which can comprise one or more layers of:

- (i) a linear low density polyethylene of any C4 to C8 alpha olefin as copolymer in any proportion with a density below 0.930 g/mL, for example a density of 0.917
20 g/mL to 0.927 g/mL, and melt index of 0.3 to 10, such as Nova Chemical AST FP-026F;
- (ii) a low density polyethylene with a melt index of 0.3 – 30, such as Eastman Tenite™ E6838-969F;
- (iii) a medium or high density polyethylene having a density above 0.930 and melt
25 index between 0.5 – 30, such as Eastman Tenite™ M2004P;

- (iv) a 6 – 24 % ethylene vinyl acetate (EVA) with melt index of 0.5 – 30
- (v) polypropylene, such as Basell PDC1208 homopolymer (which has a melt flow rate of 6, with a likely range of 4 to 8), or Basell SA861 random copolymer of ethylene (which has a melt flow rate of 6, with a likely range of 4 to 8); or
- 5 (vi) any combination thereof.

Alternatively, the reflective film is a polyethylene film composite which comprises three layers in which the middle Portion B consists of kraft paper.

The ability of the polyethylene film or film composite to adhere to the construction materials can be enhanced by decreasing the degree of orientation of the polyethylene film. It has
10 surprisingly been found that oriented films shrink when heat is applied and do not adhere to the construction material as effectively as the unoriented or less oriented film, which do not shrink with the application of heat. It is therefore important to have as low an orientation as possible when strong adhesion is required. In this respect, cast films are superior to blown films for applications in which a strong adhesion is required. Cast films are only oriented in the machine
15 direction whereas blown films are oriented in both the machine and transverse directions.

Orientation refers to the relative orientation of the polymer molecules within the film. A film which is highly oriented exhibits higher crystallinity than a film that is less highly oriented. By way of example, a cast film will exhibit orientation of the polymer molecules in one direction (i.e. the machine direction), while a blown film will contain polymer molecules that are oriented
20 in both the machine and transverse directions and will therefore be less highly oriented than the cast film. Thus, there is an inverse relationship between the degree of orientation and the ability of the polyethylene film of film composite to adhere to construction materials.

One or more layers of the polyethylene film may contain additional components depending on the ultimate application of the film or the composite of which it is a part. For
25 example, in one embodiment of the present invention a middle layer of the polyethylene film is formulated to provide heat resistance. This may be achieved, for example, by including additional resins in the composition used to prepare the middle layer. Suitable resins include high density polyethylene or polypropylene. In this respect polypropylene will provide superior

heat resistance to polyethylene, since polypropylene has a melting temperature of approximately 160°C whereas high density polyethylene has a melting temperature of approximately 125°C and low density has a melting point of approximately 103°C. Additional additives that may be incorporated in the polyethylene film or film composite include, but are not limited to, calcium carbonate or other inorganic fillers, inorganic or organic pigments, mica, diatomaceous earth, or other anti-block agents.

Both of the outer surfaces of the polyethylene film or film composite are treated to obtain a surface energy of at least 35 dynes to enhance adherence of the film or film composite to the construction material and aluminum foil layer. In order to obtain a surface energy of at least 35 dynes, the film may be treated using standard techniques well known to a worker skilled in the art. For example, the film may be corona or flame treated according to standard techniques in order to obtain high surface tension. In an alternative embodiment of the present invention, the aluminum foil is coated with a primer at an in-line pre-treatment station, wherein the primer facilitates adherence of one of the outer surfaces of the polyethylene film or film composite to the foil. Alternatively, the aluminium foil may be treated using a flame or electric discharge (i.e. Corona treater) to increase the surface tension and eliminate residual oils from the surface of the foil. Suitable primers are well known to workers skilled in the art. In this embodiment, the other outer surface is treated using standard techniques, as described above.

Aluminum Foil

The reflective film of the present invention comprises a layer of aluminum foil adhered to one surface of the polyethylene film. The aluminum foil consists of converter grade aluminum foil, which is defined as any aluminum capable of being converted to a multilayer sheet by lamination with a supporting material. In the present invention the supporting material is the polyethylene film or film composite. In one embodiment the aluminum foil useful in the manufacture of the reflective film of the present invention has the following characteristics:

- Thickness: 0.00025 mil to 2 mil, $\pm 10\%$
- Chemical composition:
 - Al content: 99.00 % minimum
 - Iron silicon content: 1.00 maximum

- Copper content: 0.05 maximum
- Manganese content: 0.05 maximum
- Zinc content: 0.10 maximum
- Titanium content: 0.03 maximum
- 5 ▪ Oil free (preferable)
- Mechanical property limits and typical properties:
 - 14,000 psi O-temper maximum tensile strength, form AA (Aluminum Association Standards and Data) and CEN (European Committee for Standardization)
 - 9,300 psi typical tensile O-temper strength
 - 10 ▪ 4.2% typical elongation O-temper strength

Alloy 1145 from Alcan Aluminum Corporation is one example of an aluminum foil that can be used in accordance with the present invention, although suitable alternatives are also available from companies such as Pechiney and Alcoa.

15 Manufacture of the Reflective Film

The polyethylene film component of the reflective film of the present invention can be produced using a blown or cast film extrusion line. The compositions comprising the ingredients outlined above in relation to the three portions of the polyethylene film or film composite may be fabricated into mono-layer or multi-layer films by any technique known in the art. For example, 20 mono-layer, or multi-layer films may be produced by the well known cast film, blown film and extrusion coating techniques, the latter including extrusion onto a substrate such as kraft paper or aluminum foil. The ordinary artisan, in possession of the present disclosure, can prepare such multi-layer films without undue experimentation.

25 The multi-layer films of the present invention may be prepared by any method known in the art. For example, the multi-layer structures of this invention are readily prepared by conventional coextrusion processes, a conventional in-line or off-line lamination process or a conventional extrusion coating process, all well known in the art. In general, in a coextrusion process, the polymers are brought to the molten state and coextruded from a conventional extruder through a flat sheet die, the melt streams being combined in a coextrusion feed block or

multi-manifold die prior to exiting the die. After leaving the die, the multi-layer film structure is quenched and removed for subsequent handling.

5 In a specific embodiment, the one or more portions of the polyethylene film or film composite comprises 2 or more layers, which are coextruded using any coextrusion process known in the art. The use of coextrusion allows for the relatively simple and easy manufacture of a multi-layered polyethylene film composed of distinct layers. Each of the distinct layers of the film may perform a specific function as required by the ultimate application of the reflective film. Although one embodiment of the present invention includes coextrusion of the polyethylene film, it is noted that the polyethylene film can be bilayered or multi-layered and
10 that, regardless of form, it can be produced using any other suitable method, if desired, as would be well understood by a worker skilled in the relevant art.

When the film is produced using blown film techniques the blow up ratio is preferably less than 2.5 in order to minimise orientation. Typical blown film extrusion lines have been employed, using standard equipment and techniques known to workers skilled in the art, to
15 manufacture all, or a portion of, the polyethylene film of the present invention.

In one embodiment of the present invention all, or a portion of, the polyethylene film is formed as a tube. The tube may be collapsed and the sides of the tube allowed to bind to one another, thereby producing a polyethylene film having twice as many layers as the film in the tube form. For example, a three layer film having a thickness of 1.5 mil that is produced in the
20 form of a tube by blown film coextrusion may be collapsed to form a polyethylene film having six layers and a thickness of 3 mil. In practice the tube is collapsed through the use of a very tight nip roll at the top of the bubble in a blown film extrusion process. The use of the very tight nip roll at the top of the bubble forces the sides of the bubble to fuse to each other. In this embodiment, the surfaces of the film may be corona treated immediately after the bubble is
25 collapsed such that the resultant polyethylene film has both outer surfaces corona treated. This technique is particularly useful in situations where the outer layers of the polyethylene film need to have the same composition. In addition, the process results in a multi-layered film that does not have wrinkles.

In alternative embodiment, the tube is not fused. Instead the tube is slit on both sides thereby creating 2 sheets of all, or a portion of, the polyethylene film or film composite.

If extrusion coating is used to produce the polyethylene film or film composite, a two layer film is produced consisting of aforementioned Portions A and B and adhered to the aluminum foil using aforementioned Portion C. Alternatively, a monolayer film consisting of Portion B is produced followed by coating with Portion A and lamination of the foil to the resulting two layer film with Portion C.

In the embodiment in which the reflective film of the present invention comprises a polyethylene film composite have a middle layer consisting of kraft paper the film composite is manufactured by extrusion coating Portion A onto the Kraft paper and subsequently extrusion coating Portion C onto the opposite surface of the Kraft paper. Alternatively, Portion C is extrusion coated first, followed by Portion A.

Once the polyethylene film or film composite has been formed it is adhered to the aluminum foil to generate the reflective film of the present invention. The aluminum foil layer may be adhered to the polyethylene layer using various techniques that would be known to a worker skilled in the art. For example, the layer of aluminum foil can be adhered to the polyethylene film via extrusion coating of the film to the foil. Alternatively, the layer of aluminum foil is adhered to the polyethylene film using a heat and pressure laminator and a method comprising annealing, heating and pressing the film onto the foil and subsequently cooling the resultant reflective film. In another alternative method the layer of aluminum foil is adhered to the polyethylene film using a solvent or solvent-free lamination system using an epoxy-based adhesive. In yet another alternative method the layer of aluminum foil is adhered to the polyethylene film using an electron beam curable adhesive and an epoxy-based adhesive. As would be readily appreciated by the skilled worker, this is a non-limiting list of techniques that may be used to adhere the aluminum foil to the polyethylene film. Any method that results in a uniform adhesion of the aluminum foil to a surface of the polyethylene film is also considered to be within the scope of the present invention.

In certain applications it may be desirable to introduce a plurality of perforations through the layer of aluminum foil. The provision of perforations is particularly important in situations

where it is necessary to eliminate problems associated with trapped moisture in structural materials made of wood, which moisture can lead to rapid degradation or decay of the materials. The perforations permit the materials to "breathe". For example, when the reflective film is laminated to structural construction material such as plywood or oriented strand board, it is applied to only one major surface of the plywood which, in use, will be the inwardly facing surface, to allow free moisture to escape. This free moisture is largely due to accumulation of moisture in the plywood attributable to rain prior to the "drying in" stage of construction.

Unperforated reflective film is useful, for example, to enclose bats of insulation such as fiberglass or polyisocyanurate sheathing (insulative sheathing), or the like, which is then used to surround ductwork in air conditioning or the like. In that context, the unperforated material comprises a barrier to moisture, preventing the moisture from entering the enclosed insulation batting.

Application of the Reflective Film

In accordance with another aspect of the present invention there is provided a composite that comprises a construction material having the reflective film thermolaminated to a surface thereof. The composite is useful as radiant heat insulation in industrial, commercial and residential buildings. The aluminum foil layer is highly reflective and marginally emissive. Specifically, it reflects the infra-red waves striking its surface and re-radiates only a very small portion of that energy, effectively serving to retain heat in desired areas. The unperforated reflective film is waterproof and, therefore, may provide the additional advantage of providing protection from water.

The construction material used in the manufacture of the composite of the present invention may be a structural material, such as, but not limited to, oriented strand board (OSB), lumber based products (e.g. plywood), fibreboard or structural types of plastic sheet, or non-structural material, such as, but not limited to, Styrofoam, insulation material or non-structural types of plastic sheet such as monolithic, twin walled or triple walled polycarbonate sheet or polyisocyanurate insulative sheathing.

In one example of a structural composite of the present invention the reflective film is laminated to one surface of the construction material (e.g. roof decking) as depicted in Figure 1. Provision of the aluminum foil on one side of the decking is effective to reflect heat back in the direction from which it comes. Thus, in the summertime, the foil reflects heat back toward the sky and in the winter the foil reflects heat back in the direction of the house. Normally, the decking in accordance with the invention would be applied with the foil layer facing inwardly toward the attic of the house. The low emissive, highly reflective foil must face at least one adjacent air space (the attic) to block radiated heat transfer.

In the case of insulative foam, the aluminium foil is adhered to one or both sides of the sheathing.

To gain a better understanding of the invention described herein, the following examples are set forth. It should be understood that these examples are for illustrative purposes only. Therefore, they should not limit the scope of this invention in any way.

EXAMPLES

EXAMPLE 1: Three Portion – LDPE Reflective film + OSB Composite

1. A Cast film of Eastman LDPE E6838-808P (Melt Index (MI) = 7, Density = 0.917g/mL) was prepared and treated to 40 dynes on one side. The thickness of the film was 2 mil.
2. The LDPE film was laminated to Aluminum foil (Alcan 1145-0 having a thickness of 0.32 mil) by extrusion lamination of Nucrel[®] 3990 (MI=10.0, density = 0.940 g/mL), which is an ethylene acrylic acid copolymer of PE. The thickness of the Nucrel[®] was 0.75mil. Nucrel[®] was coated on the treated side of the LDPE film.
3. The resulting LDPE-Nucrel-Al film "2" was then treated to 40 dynes on the side opposite to the aluminum layer. A 2-layer film was then extrusion coated on the treated side. The 2-layer film consisted of 0.15 mil of AT Plastics Ateva 1615 (MI=15.0, density = 0.937

g/mL, 16% VA) and 0.6 mil of Dupont Bynel™ 3120 (MI=9.5, density = 0.948 g/mL), which is a maleic anhydride grafted PE.

4. The resulting film "3" was then treated to 40 dynes on the outside, opposite the aluminum layer.

5. The film "4" was subsequently adhered to OSB.

EXAMPLE 2: Three Portion – MDPE Reflective Film + OSB

1. A cast film of Eastman MDPE M2004-P (MI=10.5, Density = 0.942g/mL) was prepared and treated to 40 dynes on one side. The thickness of the film was 2 mil.

2. Film "1" was laminated to Al foil by extrusion lamination of Nucrel® 3990 (MI=10.0, density = 0.940 g/mL), which is an ethylene acrylic acid copolymer of PE. The thickness of the Nucrel® was 0.75mil. Nucrel® was coated on the treated side of film "1".

3. Film "2" was then treated to 40 dynes on the other side opposite to the aluminum layer and a 2-layer film was extrusion coated on the treated side. The 2-layer film consisted of the following ingredients:

- a. 0.15 mil of AT Plastics Ateva 1615 (MI=15.0, density = 0.937 g/mL, 16% VA) and;

- b. 0.6 mil of Dupont Bynel™ 3120 (MI=9.5, density = 0.948 g/mL), which is a maleic anhydride grafted PE.

4. Film "3" was then treated to 40 dynes on the outside.

5. Film "4" was subsequently adhered to OSB.

EXAMPLE 3: Three Portion – Reflective Film + OSB

1. A Cast film of Eastman E6838-808P was prepared and treated to 40 dynes on one side. The thickness of the film was 2 mil.

2. Film "2" was laminated to Al foil by extrusion lamination of Nucrel® 3990 (MI=10.0, density = 0.940 g/mL). The thickness of the Nucrel® was 0.75mil. Nucrel® was coated on the treated side of film "2".
3. Film "3" was then treated to 40 dynes on the side opposite to the aluminum layer. A 2-layer film was extrusion coated on the treated side. The 2-layer film contained the following ingredients:
 - a. 0.15 mil of AT Plastics Ateva 1615 (MI=15.0, density = 0.937 g/mL, 16% VA) and;
 - b. 0.6 mil of AT Plastics Ateva 1010A (MI=10.5, density = 0.942 g/mL, 9% VA).
4. Film "4" was then treated to 40 dynes on the outside.
5. Film "5" was subsequently adhered to OSB.

EXAMPLE 4: Two Portion Reflective Film

1. A two-layer cast film consisting of layer (a) Eastman E6838-808P (MI=7.0, density 0.917 g/mL) and layer (b) consisting of a blend of 75% of Ateva 1010A + 25% Bynel 2002 (MI=10.0).
 - a. Two different thicknesses were produced where:
 - i. A 3 mil film consisting of 2 mil of layer (a) and 0.6 mil of layer (b)
 - ii. A 2.5mil film consisting of a 1.5mil of layer (a) and 0.6 mil of layer (b)
2. Layer (a) was then treated to 42 dynes on the outside.
3. A 0.4mil coating of 100% Nucrel AE (MI=11.0) was applied onto layer (a) using an extrusion coating machine.
4. The exterior layer (layer (b) consisting of the EVA/Bynel blend) was then treated to 42 dynes.

EXAMPLE 5: Two Portion Reflective Film

1. A two-layer cast film consisting of layer (a) Eastman E6838-808P (MI=7.0, density 0.917 g/mL) and layer (b) consisting of a blend of 50% of Ateva 1010A + 50% Nucrel AE (MI=11.0).
- 5 a. Two different thicknesses were produced where:
 - i. A 3 mil film consisting of 2 mil of layer (a) and 0.6 mil of layer (b)
 - ii. A 2.5mil film consisting of a 1.5mil of layer (a) and 0.6 mil of layer (b)
2. Layer (a) was then treated to 42 dynes on the outside.
3. A 0.4mil coating of 100% Nucrel AE (MI=11.0) was applied onto layer (a) using an
10 extrusion coating machine.
4. The exterior layer (layer b consisting of the EVA/Nucrel AE blend) was then treated to 42 dynes.

EXAMPLE 6:

- 15 1. A two-layer cast film consisting of layer (a) Eastman E6838-808P (MI=7.0, density 0.917 g/mL) and layer (b) consisting of a pure layer of Ateva 1615 (MI=15).
 - a. Two different thicknesses were produced where:
 - i. A 3 mil film consisting of 2 mil of layer (a) and 0.6 mil of layer (b)
 - ii. A 2.5mil film consisting of a 1.5mil of layer (a) and 0.6 mil of layer (b)
- 20 2. Layer (a) was then treated to 42 dynes on the outside.
3. A 0.4mil coating of 100% Nucrel AE (MI=11.0) was applied onto layer (a) using an extrusion coating machine.

4. The exterior layer (layer b consisting of the EVA) was then treated to 42 dynes.

EXAMPLE 7: Two Portion Reflective Film

1. A two-layer cast film consisting of layer (a) Eastman E6838-808P (MI=7.0, density 0.917 g/mL) and layer (b) consisting of a pure layer of Bynel 3120 (MI=9.5).

- 5 a. Two different thicknesses were produced where:

i. A 3 mil film consisting of 2 mil of layer (a) and 0.6 mil of layer (b)

ii. A 2.5mil film consisting of a 1.5mil of layer (a) and 0.6 mil of layer (b)

2. Layer (a) was then treated to 42 dynes on the outside.

3. A 0.4mil coating of 100% Nucrel AE (MI=11.0) was applied onto layer (a) using an
10 extrusion coating machine.

4. The exterior layer (layer b consisting of the Bynel) was then treated to 42 dynes.

EXAMPLE 8: Comparison of Formulations and Process Conditions

Reflective films consisting of laminated composites of aluminum foil supported with plastic films were prepared having the following three formulations:

15 **Table 1: Formulation Ingredients**

Component	Formulation 1	Formulation 2	Formulation 3
Aluminum layer	Aluminum foil (0.32 mil)	Aluminum foil (0.32 mil)	Aluminum foil (0.32 mil)
Portion C	Nucrel [®] (0.43 mil)	Nucrel [®] (0.43 mil)	Nucrel [®] (0.43 mil)
Portion B	LDPE (2.0 mil)	mMDPE (2.0 mil)	LDPE (2.0 mil)
Portion A	EVA (16 %) (0.15 mil)	EVA (16 %) (0.15 mil)	EVA (16 %) (0.15 mil)
	Bynel [™] (0.6%) (0.30 mil)	Bynel [™] (0.6%) (0.30 mil)	EVA (9 %) (0.15 mil)
	Bynel [™] (0.6%) (0.30 mil)	Bynel [™] (0.6%) (0.30 mil)	EVA (9 %) (0.15 mil)

A sample of each of the three reflective films was laminated onto an OSB panel. The OSB panels were preheated in an air convection oven up to the point that its surface temperature has reached 270°F (132°C). A slightly higher oven temperature set point of approximately 150°C was required to achieve this panel preheating. The preheating simulated panel temperature just after panel manufacturing.

The reflective films were then sandwiched between the hot OSB panels and a metallic plaque. After a 5 second preheating stage inside a press at a defined temperature, compression at fixed pressure was applied for a certain processing time (5 seconds in most cases). Following the compression stage the reflective films were fully bound to the OSB panels. In each case, the reflective film on half of the panel was perforated to allow adhesion testing of both virgin and perforated parts following the post-curing stage.

Post-curing was performed in an oven to simulate the stacking of hot OSB panels during storage. The simulated temperature profile is depicted in Figure 2, which is based on the assumption that the panels reach a temperature of 90°F (32°C) after 4 days.

Trials

Various processing temperatures were tested. The selection of the temperatures tested was based on the softening and melting points of the plastic layer in contact with the OSB panel. For example, the softening temperature and melting point of Bynel™ (in formulations 1 and 2) are 57°C and 87°C, respectively, and the softening temperature and melting point of EVA (in formulation 3) are 82°C and 102°C, respectively. Therefore, for formulations 1 and 2, the processing temperatures tested were 75, 90, 120 and 160°C. The processing temperatures tested for formulation 3 started slightly higher and were 90, 105, 120 and 160°C. In addition, two processing pressure levels were also investigated.

With the exception of the intermediate pressure and temperature levels, additional experimental points were performed to study other aspects of the process, such as the effect of post-curing treatment in an oven for simulating actual storage, of the use of a cold panel directly

without preheating, of the use of a panel having a scratched wood surface, etc. The processing conditions studied are summarised in Table 2.

Table 2: Processing Condition Studies

Panel #	Formulation	Temperature (°C)	Pressure (psi)	Compression time (s)	Panel treatment
1	1	75	40	5	N
2	1	75	110	5	N
3	2	75	40	5	N
4	2	75	110	5	N
5	3	90	40	5	N
6	3	90	110	5	N
7	1	90	40	5	N
8	1	90	110	5	N
9	2	90	40	5	N
10	2	90	110	5	N
11	3	105	40	5	Y
12	3	105	110	5	Y
13	1	120	40	5	N
14	1	120	110	5	N
15	2	120	40	5	Y
16	2	120	110	5	Y
17	3	120	40	5	Y
18	3	120	110	5	Y
19B*	1	160	40	5	N
19	1	160	40	5	N
20	1	160	110	5	N
21	2	160	40	5	N
22	2	160	110	5	Y
23	3	160	40	5	N
24	3	160	110	5	N
25	1	120	75	5	N
26	2	120	75	5	Y
27	3	120	75	5	N

Panel #	Formulation	Temperature (°C)	Pressure (psi)	Compression time (s)	Panel treatment
28	1	120	40	5	N + scratch
29	1	90	110	20	Y
30	1	105	110	5	Y
31*	1	105	110	5	N
32**	1	105	110	20	Y
33*	3	90	20	3	Y
34*	3	90	20	6	Y
35*	3	90	110	6	Y
36*	3	160	20	6	Y

* was not post-cured in the oven.

** was not post-cured in the oven and cold panel was used directly.

Panels 33, 34, 35 and 36 were preliminary trials employed to set up the investigation processing window.

Testing

A peel test was developed to study the effect of the processing and formulation conditions on the adhesion between the reflective film and the wood panel. The test makes use of the INSTRON™ 4411 machine.

- 0 Pre-testing evaluations were performed to develop the peel test methodology. These evaluations demonstrated that inter-grip distance does not appear to affect the measured peel strength (See Figure 3). The variability in the measured peel strength was mainly due to non-homogeneity of the panels resulting from, for example, non-homogeneity of the wood surface roughness, variations in the thickness of the panels and/or the presence or absence of paint. The absolute standard deviation is approximately 23%, however, this relatively high value reflects the non-homogeneity of adhesion on such wood OSB panels.
- 15

In contrast to the effect of inter-grip distance, it was found that grip speed does have a relatively significant effect on peel strength, as shown in Figure 4.

As a result of the pre-testing evaluations the following conditions were selected for performing the peel test of the panels identified in Table 2:

- 6" x 4" sample
- a minimum of 3 tested strips
- 5 - peeling speed of 5"/minute
- inter-grip distance of 1 inch

Results

In each case the panels were tested in the virgin (i.e. unperforated) region. The peel strength results are summarised in Table 3, in which "adhesion > substrate" indicates that the adhesion is so strong that the aluminum foil supported by the polyethylene film portion of the reflective film breaks rather than peels.

Table 3: Peel Strengths of Panels

Panel #	Formulation	Temperature (°C)	Pressure (psi)	Compression time (s)	Panel treatment	Peel Strength (psi)
1	1	75	40	5	N	adhesion > substrate
2	1	75	110	5	N	adhesion > substrate
7	1	90	40	5	N	1276.79
8	1	90	110	5	N	1647.8
13	1	120	40	5	N	924.49
14	1	120	110	5	N	1217.91
19B*	1	160	40	5	N	adhesion > substrate
19	1	160	40	5	N	adhesion > substrate
20	1	160	110	5	N	adhesion > substrate
25	1	120	75	5	N	adhesion > substrate

Panel #	Formulation	Temperature (°C)	Pressure (psi)	Compression time (s)	Panel treatment	Peel Strength (psi)
28	1	120	40	5	N + scratch	adhesion > substrate
29	1	90	110	20	Y	adhesion > substrate
30	1	105	110	5	Y	adhesion > substrate
31*	1	105	110	5	N	655.15
32**	1	105	110	20	Y	846.95
3	2	75	40	5	N	548.58
4	2	75	110	5	N	669.26
9	2	90	40	5	N	651.45
10	2	90	110	5	N	852.88
15	2	120	40	5	Y	988.43
16	2	120	110	5	Y	adhesion > substrate
21	2	160	40	5	N	adhesion > substrate
22	2	160	110	5	Y	adhesion > substrate
26	2	120	75	5	Y	754.91
5	3	90	40	5	N	831.16
6	3	90	110	5	N	635.3
11	3	105	40	5	Y	635.17
12	3	105	110	5	Y	660.11
17	3	120	40	5	Y	592.45
18	3	120	110	5	Y	630.41
23	3	160	40	5	N	adhesion > substrate
24	3	160	110	5	N	adhesion > substrate
27	3	120	75	5	N	adhesion > substrate
33*	3	90	20	3	Y	77.68
34*	3	90	20	6	Y	99.71
35*	3	90	110	6	Y	571.63

Panel #	Formulation	Temperature (°C)	Pressure (psi)	Compression time (s)	Panel treatment	Peel Strength (psi)
36*	3	160	20	6	Y	796.1

* was not post-cured in the oven.

** was not post-cured in the oven and cold panel was used directly.

Figure 5 summarises the influence of formulation and processing temperature and pressure on adhesion. An arbitrary value of 2000 psi was assigned for those samples when adhesion was too strong to be measured (i.e. adhesion > substrate).

Identical peel tests were performed using the region of the panels that was perforated during the manufacture. Only those panels processed at 110 psi were tested. These studies demonstrated the effect of the perforation on the strength of adhesion to the panels. As depicted in Figure 6, perforation does not appear to affect adhesion strength since identical peel strengths were observed for the non-perforated and perforated regions of the same panels.

Peel strength was also tested after ageing of panels in water at room temperature (~20°C). These studies were performed using panels 2, 16 and 27, which are those panels that exhibited strong adhesion and were prepared using the least stringent conditions and formulations 1, 2 and 3, respectively. A panel that was laminated using a reflective film in which the aluminum foil layer is supported by kraft paper was also tested. The effect of ageing on peel strength is shown in Figure 7. The OSB panel laminated with the reflective films comprising aluminum foil supported by the plastic film demonstrated better ageing characteristics (i.e. better adhesion) than the OSB panel laminated with the reflective film in which the aluminum foil layer is supported by kraft paper.

Conclusions

As a result of the peel strength studies, the following conclusions were made:

- Adhesion using dry conditions was found to be more effective than wet conditions when using reflective films in which the aluminum foil was supported by plastic film alone rather than a kraft paper composite.

- Irrespective of the temperature and formulation, the higher the processing pressure the stronger the adhesion.
- Irrespective of the formulation, the use of a very high processing temperature (e.g. 160°C) resulted in very strong adhesion.
- 5 – Wrinkles due to the intrinsic manner of applying the aluminum foil on the OSB panel are more numerous and pronounced at higher processing temperatures, however, the use of high processing temperatures can dramatically diminish immediate scratch resistance.
- Use of Bynel™ rather than EVA as the contact layer with the OSB panel favours better adhesion.
- 10 – Combining Bynel™ with an LDPE middle portion achieved better adhesion at low temperature than the use of the formulation in which Bynel™ was combined with a middle portion consisting of MDPE.
- The post-curing stage provides better adhesion, at least when Bynel™ is used (compare panel 30 to 31). This enhancement is more pronounced when rather low processing temperatures
15 are used (compare panels 19 and 19B to panels 30 and 31).

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to
20 be included within the scope of the following claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A reflective film for adhesion to a construction material, which reflective film comprises a layer of converter grade aluminum foil, preferably soft and oil-free, having a thickness of between about 0.00025 mil and about 2 mil adhered to one surface of a polyethylene film or film composite, said polyethylene film or film composite having a surface energy of at least 35 dynes and consisting of:
 - (a) a first outer portion suitable for adhesion to the construction material consisting of one or more layers of:
 - (i) a 6 – 28% EVA with melt index of 0.5 – 30;
 - (ii) a metallocene catalyzed polyethylene with density below 0.905 g/mL and melt index between 0.5 – 30;
 - (iii) an acid modified copolymer of polyethylene with a melt index of 0.5 to 30;
 - (iv) an ionomer with a melt index of 0.5 to 30;
 - (v) an ethyl methyl acrylate polyethylene copolymer with a melt index of 0.5 to 30;
 - (vi) an ethyl butyl acrylate polyethylene copolymer with a melt index of 0.5 to 30;
 - (vii) an ethyl ethylene acrylate polyethylene copolymer with a melt index of 0.5 to 30; or
 - (viii) a combination of one or more of (i), (ii), (iii), (iv), (v), (vi), or (vii) alone or blended with between 0 and 80 % of a low density polyethylene having a melt index of 0.3 – 30; and

- (b) a second outer portion adhered to the layer of aluminum foil and consisting of one or more layers of:
 - (i) an ethylene acrylic acid modified polyethylene;
 - (ii) an ionomer;
 - (iii) a low density polyethylene with a melt index between 0.5 – 30; or
 - (iv) a combination thereof.
- 2. The reflective film according to claim 1, which additionally includes a middle portion consisting of one or more layers of
 - (i) a low density polyethylene with a melt index of 0.3 – 30;
 - (ii) a linear low density polyethylene with a density below 0.930 g/mL and melt index between 0.5-30;
 - (iii) a polyethylene with a density of above 0.930 g/mL and melt index between 0.5 – 30;
 - (iv) a 6 – 24 % EVA with a melt index of 0.5 – 30;
 - (v) a polypropylene;
 - (vi) any combination of two or more of (i), (ii), (iii), (iv) or (v); or
 - (vii) kraft paper.
- 3. The reflective film of claim 1 or 2, wherein layer of aluminum foil is adhered to the polyethylene film or film composite via extrusion coating of the film to the foil.
- 4. The reflective film of claim 1 or 2, wherein layer of aluminum foil is adhered to the polyethylene film or film composite using a heat and pressure laminator and a method comprising annealing, heating and pressing the film onto the foil and cooling the resultant reflective film.

5. The reflective film of claim 1 or 2, wherein layer of aluminum foil is adhered to the polyethylene film or film composite using a solvent or solvent-free lamination system using an epoxy-based adhesive.
6. The reflective film of claim 1 or 2, wherein layer of aluminum foil is adhered to the polyethylene film or film composite using an electron beam curable adhesive and an epoxy-based adhesive.
7. A composite material comprising the reflective film of any one of claims 1 to 6 laminated to one side of a construction material, wherein the polyethylene film or film composite is directly adhered to the construction material such that the layer of aluminum foil forms a surface of the composite material.

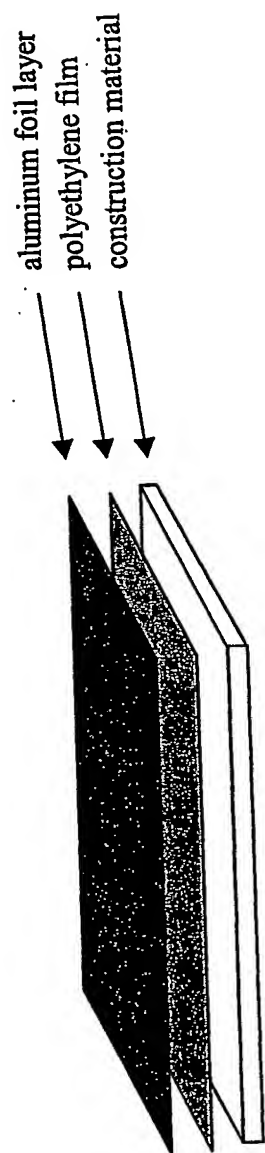


FIGURE 1

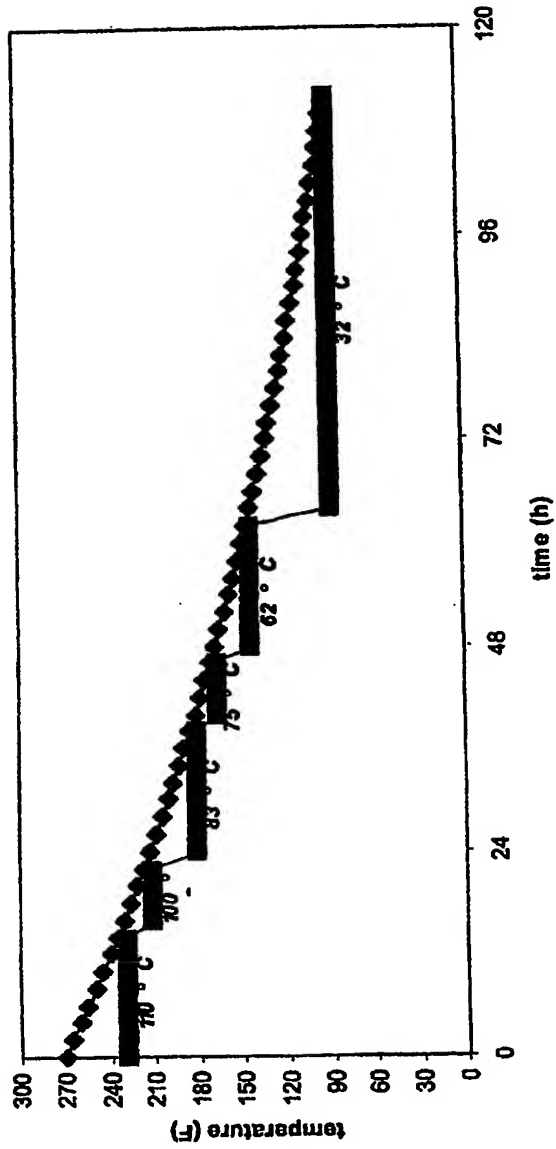


FIGURE 2

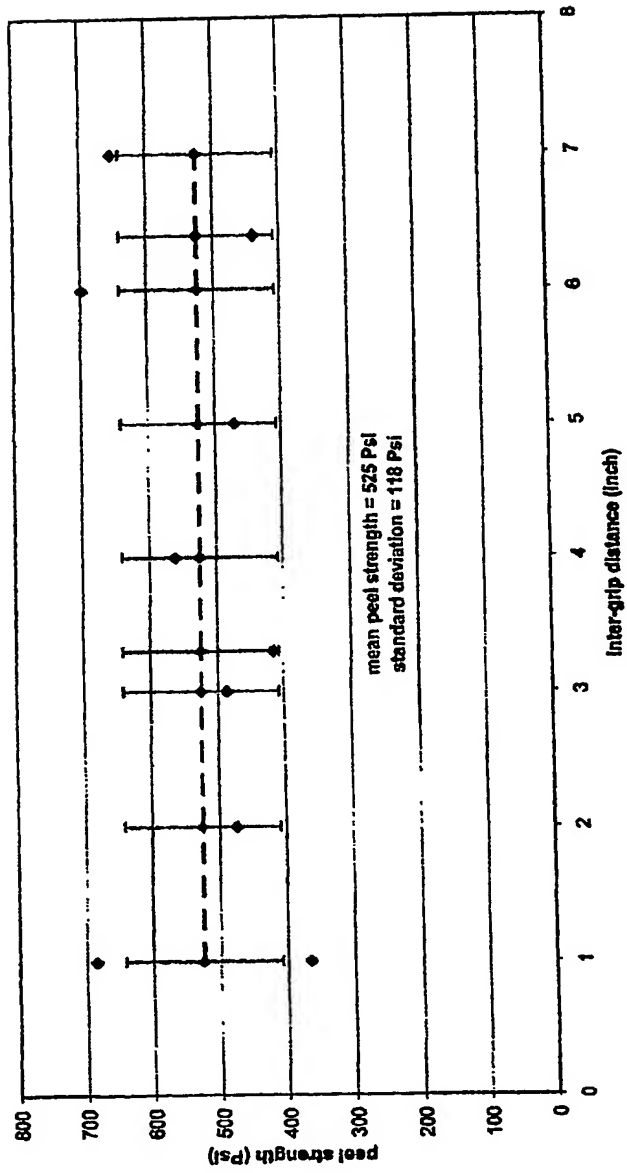


FIGURE 3

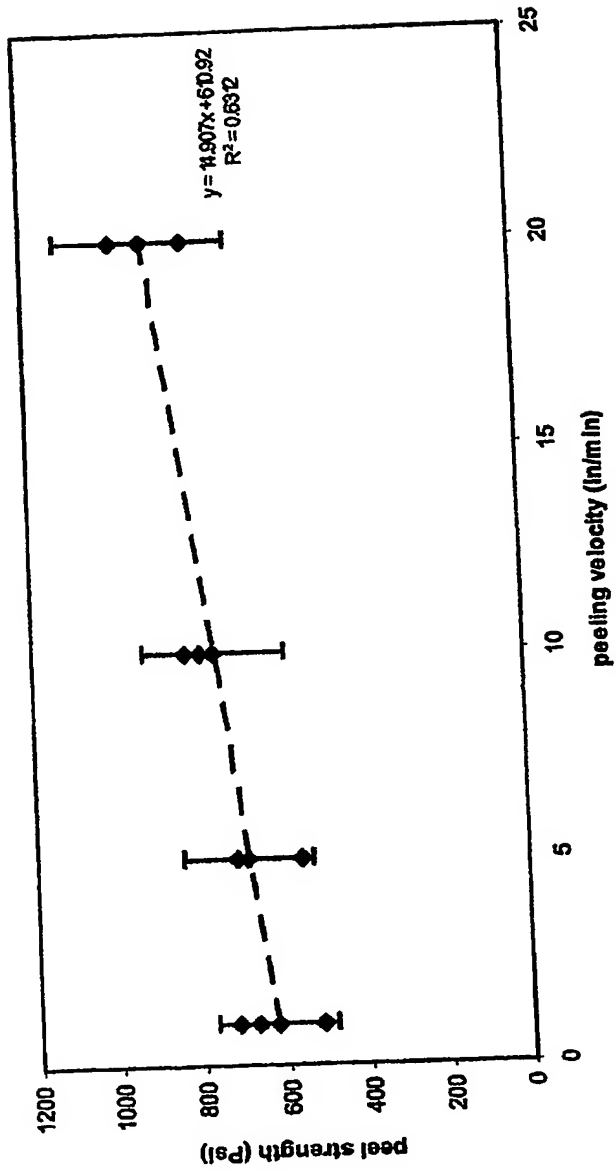


FIGURE 4

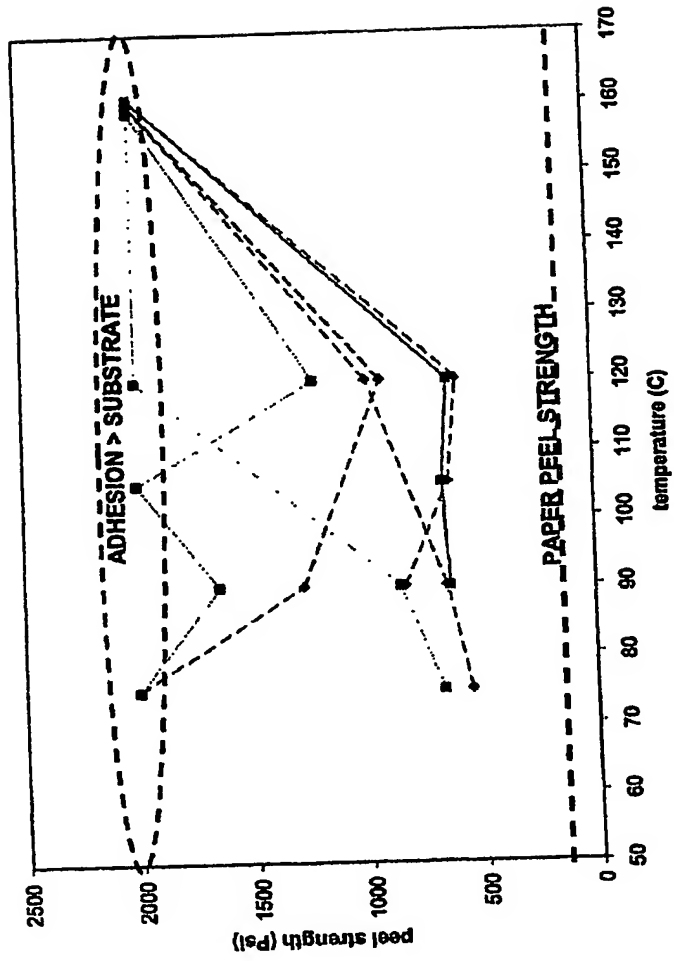


FIGURE 5

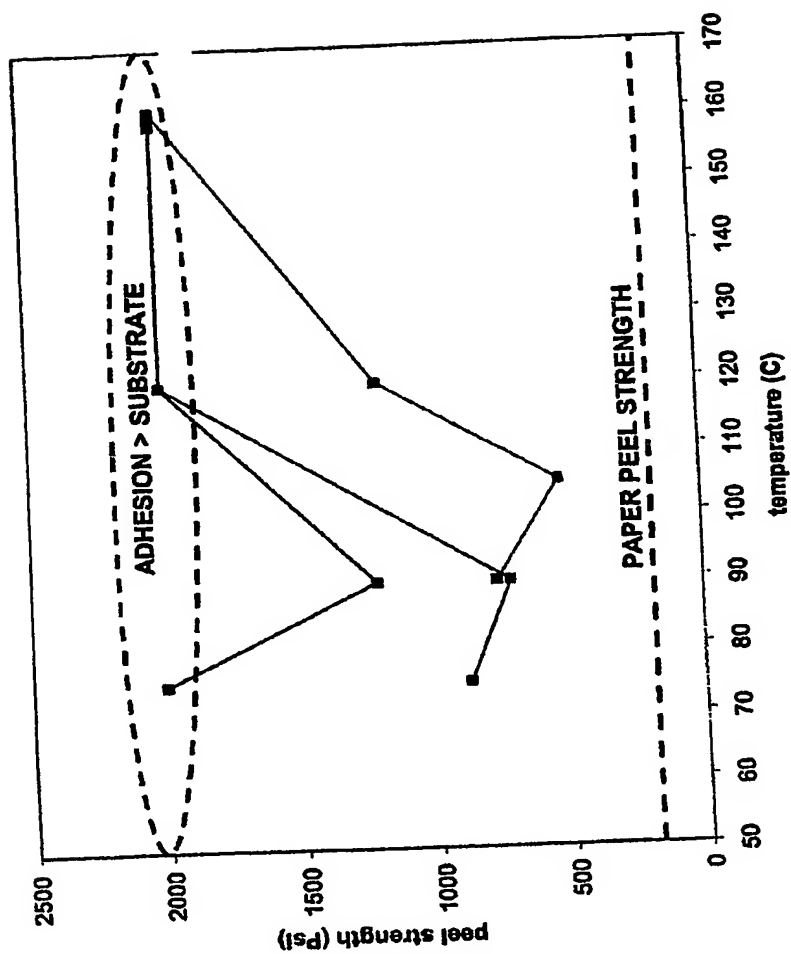


FIGURE 6

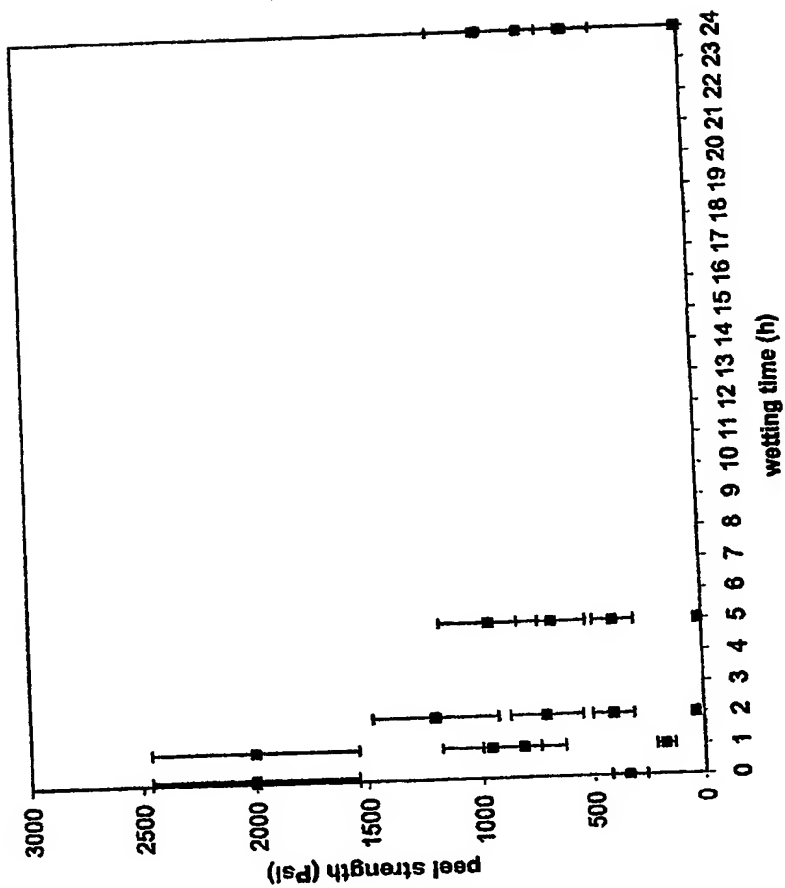


FIGURE 7